

The 2MASS Tully–Fisher Survey : Mapping the Mass in the Universe

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Abstract. The 2MASS Tully-Fisher Survey (2MTF) aims to measure Tully-Fisher (TF) distances for all bright inclined spirals in the 2MASS Redshift Survey (2MRS) using high quality HI widths and 2MASS photometry. Compared with previous peculiar velocity surveys, the 2MTF survey provides more accurate width measurements and more uniform sky coverage, combining observations with the Green Bank, Arecibo and Parkes telescopes. With this new redshift-independent distance database, we will significantly improve our understanding of the mass distribution in the local universe.

Keywords. galaxies: distances and redshifts — galaxies: spiral — radio emission lines — catalogs — surveys

1. Introduction

The Tully-Fisher relation is an empirical relation between the luminosity and rotational velocity of spiral galaxies (Tully & Fisher 1977). As a secondary distance indicator, the Tully-Fisher relation is a good tool for measuring the redshift-independent distances of local spiral galaxies. With these redshift independent distances, we can calculate the peculiar velocity field, which in turn allows us to trace the mass distribution of the local universe.

In the last few decades, a number of Tully-Fisher surveys have been conducted, including those described in Giovanelli et al. (1997b); Springob et al. (2007); Tully et al. (2008), which are typically limited by source selection criteria and sky-coverage. For instance, the SFI++ survey (Springob et al. 2007), which is the largest Tully-Fisher survey to date, was selected optically in I-band and can only cover Galactic latitudes down to $|b| = 15^\circ$. This sky-coverage is a significant limitation on the measurement of an all-sky peculiar velocity field, especially in the Zone of Avoidance (ZoA; the part of the sky which is difficult to be observed because of dust and source crowding in our own Galaxy).

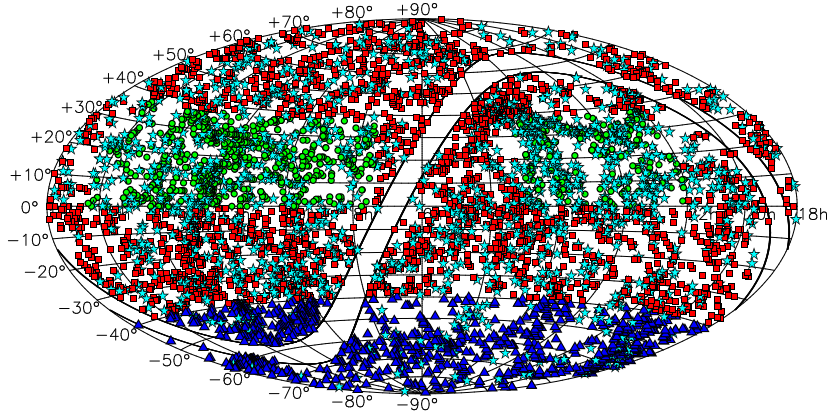


Figure 1. The distribution of 6,000 2MTF target galaxies. The red squares indicate the GBT observed galaxies, Parkes observed galaxies are plotted by blue triangles, the green circles show the ALFALFA galaxies, and the cyan stars are galaxies with archival data. The thick lines trace the galactic latitudes $b = 5^\circ$ and $b = -5^\circ$.

Thus, a new all-sky Tully-Fisher survey with uniform source selection and sky-coverage is needed for the study of the local peculiar velocity field. This new survey will improve our model of the mass distribution of the local Universe.

2. 2MASS Tully-Fisher Survey

The 2MASS Tully-Fisher Survey (2MTF), which is based on a source list selected from the 2 Micron All-Sky Survey (2MASS), will provide better statistics and more even sky coverage than previous surveys, in particular greatly reducing the impact of the ZoA. This survey will make use of existing high quality rotation widths, new HI widths, and 2MASS photometry to measure Tully-Fisher distances for all bright inclined spirals in the 2MASS Redshift Survey (2MRS, Huchra et al. 2012).

2.1. Source selection

To minimize the error in the final Tully-Fisher distances, we selected only bright and highly-inclined galaxies from 2MRS with a limit of $K_s = 11.25$ mag, $cz < 10,000$ km s⁻¹, and axial ratio $b/a < 0.5$. The target sample contains approximately 6,000 galaxies, which covers more than 90% of the whole sky, where the missing 10% is due to the Milky Way. 35% of these galaxies have rotation width measurements for Tully-Fisher distances already available from the literature, but with very uneven sky coverage. Figure 1 shows the distribution of 6,000 target galaxies.

2.2. Current Data Status

Our new HI line observations contain about 1,300 galaxies observed with high velocity resolution, conducted with the Green Bank Telescope (GBT) and the Parkes Telescope between Feb 2006 to Feb 2012. When complete in 2012, the ongoing Arecibo Legacy Fast ALFA survey (ALFALFA, Giovanelli et al. 2005) survey will also provide high velocity resolution widths for all HI rich galaxies in the high galactic latitude Arecibo sky.

2.2.1. New Observations in GBT and Parkes Telescope

In the northern sky ($\delta > -40^\circ$), we observed about 1,000 galaxies using the GBT in the 06A, 06B and 06C semesters. Observations were done in position switched mode, always in pairs of 5 mins ON/OFF with a 12.5 MHz bandwidth and 8192 channels.

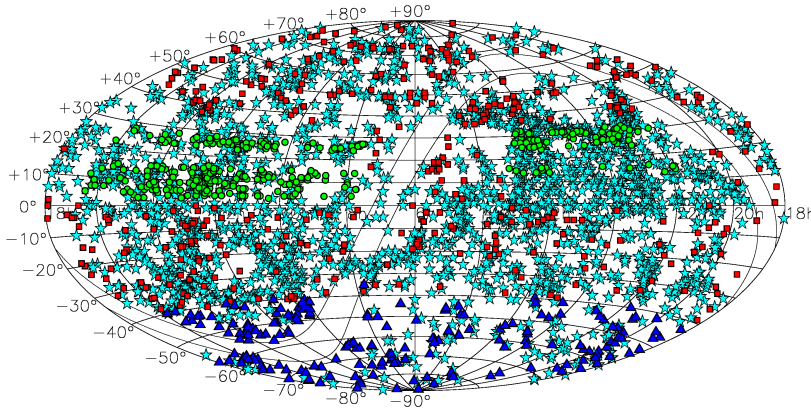


Figure 2. The distribution of the final sample of 3,000 2MTF galaxies (pending the addition of the remaining ALFALFA galaxies). All symbols share the same meaning as in Figure 1

In the sky south of -40° , 305 galaxies which meet our selection criteria were considered to be observable at Parkes without confusion. In six semesters (06OCTS, 07APRS, 07OCTS, 08APRS, 08OCTS and 11OCTS) at Parkes, we have observed all of these 305 galaxies using the 20cm multi-beam receiver in beam switching mode with a bandwidth of 8 MHz and 1024 spectral channels.

To obtain the lowest possible error in Tully-Fisher distances, we have to minimize the error (less than 10%) on the measurements of rotation widths. We require $S/N > 10$ to measure the widths to better than 10%. From these new observed HI lines, we got 386 high quality HI width measurements from GBT data, and also obtained 152 high quality HI spectra from Parkes.

2.2.2. ALFALFA 40% Data

ALFALFA is a large blind HI survey being undertaken with the Arecibo telescope. It covers the high galactic latitude Arecibo sky, and will be completed in late 2012. More than 30,000 extragalactic HI sources will be detected by ALFALFA with redshift up to $z \sim 0.06$.

40% of the ALFALFA data ($\sim 15,900$ HI sources) have been published by Haynes et al. (2011). After cross-matching with our 2MTF target sample, we found 357 useful widths for our Tully-Fisher calculations. We still await the full data release, so that we may complete our sample.

2.2.3. Archived Data

The archived HI widths are mainly from the SFI++ database (Springob et al. 2005). Besides the SFI++ data, we also selected HI widths from more than 10 additional catalogs in the literature. About 2,000 archived HI data sources matched our 2MTF target sample, and 1,800 widths have accuracy better than 10%.

Our final sample (pending the addition of the remaining ALFALFA galaxies) includes roughly 3,000 useful HI widths with uniform distribution in total. This includes all of the newly observed galaxies, the ALFALFA 40% data and the archival data. The spectroscopic data will be published and made available online shortly. The data releasing and analyzing papers are also in prepare (Masters et al. 2012, to be submitted; Hong et al. 2012, to be submitted). Figure 2 shows the sky distribution of the 2MTF final sample, and Figure 3 shows the histograms of the galaxies' central velocities and HI widths.

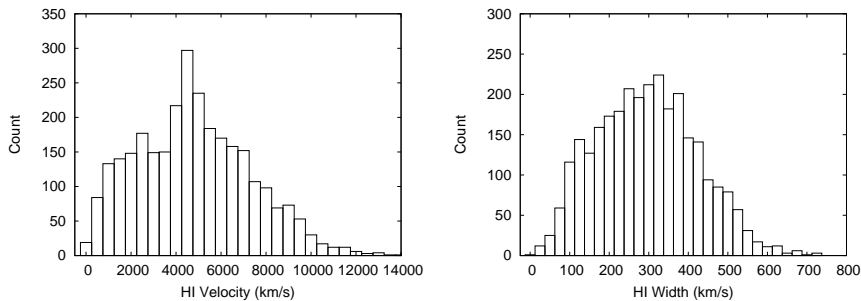


Figure 3. The central velocity and HI width histograms of the final 2MTF sample.

2.3. New Near-IR Tully-Fisher Template

A universal Tully-Fisher calibration in the near-infrared bands is very important for the 2MTF project. Masters et al. (2008) built a new Tully-Fisher template in the 2MASS K, H and J bands using the “basket of clusters” method (Giovanelli et al. 1997a), with a sample containing 888 galaxies in 33 clusters.

Masters et al. (2008) also split the full sample into three sub-samples by galaxy morphology, and determined that the Tully-Fisher relation depends on galaxy morphology in all three 2MASS bands, with later type galaxies having a steeper Tully-Fisher slope and a fainter zero point than earlier type galaxies. (see Masters et al. 2008, figure 4).

Masters et al. (2008) corrected the final relation to that for Sc galaxies, and this relation will be used as the universal template for the 2MTF calculations.

3. Conclusion

2MTF project is an all-sky Tully-Fisher survey, will measure Tully-Fisher distances of all bright highly-inclined galaxies in the local universe. Comparing with previous Tully-Fisher surveys, the 2MTF project provides more even sky-coverage and a smaller “Zone of Avoidance”, and will be a better sample for measuring the peculiar velocity field in the local universe. The final 2MTF sample contains about 3,000 high quality HI widths, all selected from the 2MASS Redshift Survey. The sample contains three parts, the new observed HI widths by our group using the GBT and Parkes telescope, the ALFALFA HI widths and the archived high quality HI widths from the literature. A new calibration of the Near-IR Tully-Fisher relation has been made and published. The 2MTF project will help us to study and understand the peculiar velocity field in the local universe, using the 2MTF data, we will provide better constraints on the local bulk flow, dipole motion and mass distribution.

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